Chapter 1 – Background Information

INTRODUCTION

The National Park Service (NPS) has instituted a program to inventory and monitor natural resources in approximately 270 park units across the nation. The program is being implemented by forming 32 ‘networks’ of parks that share common management concerns and geography. By funding these networks, the NPS hopes to minimize redundancy, maximize cost effectiveness, and increase consistency in data collection and information transfer.

The Great Lakes Inventory and Monitoring Network (hereafter, GLKN or the Network; see Appendix B for a list of acronyms) is composed of nine national park units in Minnesota, Wisconsin, Michigan, and Indiana (Figure 1.1). The Network was formed in 1999 and began implementing a biological inventory program in 2000 (Route 2000). The Network’s biological inventory program is designed to gather baseline information on vertebrates and vascular plants in the nine parks, including cataloging existing information and implementing field inventories to fill critical knowledge gaps. Simultaneously, other programs within the NPS are gathering and summarizing information on air and water resources; developing state-of-the-art maps of vegetation, soils, and geology; and designing web-based data systems for easy access to information throughout the NPS. These efforts were made possible by one of the largest increases in funding and staffing for natural resource management in the history of the NPS.

The Network received funding in 2002 to begin planning its **Vital Signs** monitoring program. (Words and phrases that are bolded within the text can be found in the glossary, Appendix C.) Herein we describe the purpose and goals of the monitoring program, the prioritized list of what the Network intends to monitor, and how we intend to carry out such monitoring over the next six years.

Developing an ecological monitoring program requires an initial investment in planning and design to ensure that critical information needs are met and that results are clearly understood and readily available. Each network is required to design a monitoring program that addresses the Servicewide goals, yet is flexible enough to meet local ecological and managerial needs. To determine appropriate strategies and **indicators**, all networks are expected to take a phased approach to planning that incorporates five steps that are reported in this Phase III Report:

<u>In Phase 1:</u>

1. Catalog and summarize existing data and knowledge of park **ecosystems**.
2. Develop conceptual models of relevant ecosystem components.

<u>In Phase 2:</u>

3. Develop specific monitoring objectives and select indicators.

<u>In Phase 3:</u>

4. Determine the appropriate sampling design and sampling protocols.
5. Implement data management, analysis, and reporting procedures.

Figure 1.1. Location of the nine National Park Service units that comprise the Great Lakes Inventory and Monitoring Network. Land cover background is from the National Land Cover Dataset by the U.S. Geological Survey (from Landsat imagery circa 1990). Dark green is evergreen forest while lighter greens are mixed and deciduous forest. Yellows and orange show agricultural crop lands, pasture, meadow, and other open grasslands. Red and pink identify urban centers and residential areas respectively.

Table 1.1 shows the timeline and progress of the Great Lakes Network in the completion of the three-phased process. Throughout this process GLKN gave equal consideration to air, geologic, terrestrial, and aquatic systems in the nine parks. The only preconceived Vital Signs were core water quality indicators required by the NPS Water Resources Division (WRD) including pH, specific conductance, dissolved oxygen, temperature, and flow/water level in those waterbodies being monitored.

In Phase 3 we began integrating our monitoring with current park- and partner-funded efforts. This integration involved a blend of strategies including: 1) incorporating data from ongoing park and partner monitoring, 2) augmenting park-based monitoring, 3) commissioning partners to conduct monitoring, and 4) having Network teams conduct monitoring. Regardless of who collects the data, for all Network-initiated monitoring programs the Network will be responsible for design, quality control, data archival, analysis, and reporting.

Table 1.1. Timeline for the Great Lakes Inventory and Monitoring Network to complete the 3-phase process of planning and designing a long-term ecological monitoring program. An Inventory and Monitoring Advisory Committee (IMAC) of national, regional, Network, and park staff determines deadlines for major steps and reports.

Planning and design step	FY2000	FY2001	FY2002	FY2003	FY2004	FY2005	FY2006
Gather information and catalog data	X	X	X	X	X	X	
Conduct inventories to support monitoring		X	X	X	X	X	
Hold park scoping workshops		X	X				
Develop conceptual models			X	X			
Prioritize and select indicators					X		
Develop protocols and monitoring designs					X	X	X
Implement initial monitoring							X
Monitoring plan due dates Phase reports 1, 2, 3					Phase 1 Oct. 03	Phase 2 Oct. 04	Phase 3 Dec. 05

Purpose of Long Term Ecological Monitoring in National Parks

National park managers are mandated to understand, maintain, restore, and protect the integrity of natural resources (e.g., air, water, soils, native plants, and animals), processes (e.g., erosion, succession, fire, and bioaccumulation of toxics), and values (e.g., scenic views and solitude) within their boundaries (NPS 2001). Yet managers are confronted with increasingly complex and challenging issues that require an understanding of the status and trends of park resources.

A long-term approach to natural resource monitoring is needed because short-term studies cannot adequately represent cyclic phenomena, often miss significant transitory events, cannot adequately track incremental changes in resources, and are less able to detect change when there is a lag in the ecosystem response (Frederick and Ogden 2003). Furthermore, long-term studies of interannual variability have greater statistical **power** than do shorter-duration studies, and are better able to test associations of changes in resources with anthropogenic and natural factors (Larsen et al. 2001). Long-term monitoring data can also help define the normal ranges of natural variation in park resources and can provide context in which to analyze data from research. Such long-term monitoring must occur at multiple scales (both resolutions and extents) because no single temporal or spatial scale is adequate for all system components and processes. For example, the appropriate level for understanding and effectively managing a resource might be genetic, population, species, community, or landscape (Noss 1990). In some cases, effective management may require a regional, national, or international effort. National parks are part of larger ecosystems and must be managed in that context. Understanding the dynamics of park ecosystems and the consequences of human activities is essential for making decisions to maintain, enhance, or restore the **ecological integrity** of park ecosystems (Roman and Barrett 1999).

Legislation, Policy, and Guidance

National park managers are directed by federal law and NPS policies and guidance to know the status and trends of natural resources under their stewardship, as stated in the mission of the National Park Service: "*...to conserve the scenery and the natural and historic objects and the wild life therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations*" (National Park Service Organic Act 1916).

More recently, the National Parks Omnibus Management Act of 1998 established the framework for integrating natural resource monitoring into park management. Section 5934 requires the Secretary of the Interior to develop a program of "*inventory and monitoring of National Park System resources to establish baseline information and to provide information on the long-term trends in the condition of National Park System resources*."

Congress reinforced this message in its FY 2000 Appropriations bill: "*The Committee applauds the Service for recognizing that the preservation of the diverse natural elements…involves a serious commitment from the leadership of the National Park Service to insist that the superintendents carry out a systematic, consistent, professional inventory and monitoring program, along with other scientific activities, that is regularly updated to ensure that the Service makes sound resource decisions based on sound scientific data."*

The 2001 NPS Management Policies (NPS 2001) specifically directed that: *"Natural systems in the National Park System, and the human influences upon them, will be monitored to detect change. The Service will use the results of monitoring and* *research to understand the detected change and to develop appropriate management actions."*

Further, *"The Service will:*

- Identify, acquire, and interpret needed inventory, monitoring, and research, including applicable traditional knowledge, to obtain information and data that will help park managers accomplish park management objectives provided for in law and planning documents.
- Define, assemble, and synthesize comprehensive baseline inventory data describing the natural resources under its stewardship and identify the processes that influence those resources.
- Use qualitative and quantitative techniques to monitor key aspects of resources and processes at regular intervals.
- Analyze the resulting information to detect or predict changes, including interrelationships with visitor carrying capacities, that may require management intervention, and to provide reference points for comparison with other environments and time frames.
- Use the resulting information to maintain and, where necessary, restore the integrity of natural systems" (NPS 2001).

Several other important statutes, such as the Clean Water Act and the Endangered Species Act, provide legal direction for determining the condition of natural resources in parks. For a description of the legislation and policy directives relevant to the monitoring program see Appendix A, Supplemental Document 1 and on-line at: http://science.nature.nps.gov/im/monitor/LawsPolicy.htm.

Goals for Vital Signs Monitoring

The purpose of this program is to identify and monitor Vital Signs of park ecosystems. A Vital Sign may be a physical, biological, chemical element or process that: indicates the health of a park ecosystem, responds to natural or anthropogenic stresses in a predictable or hypothesized manner, or has high value to the park or the public (e.g., endangered species, charismatic species, exotic species). The NPS Vital Signs program is intended to monitor key elements of park ecosystems to help detect ecological problems that need further research or management action.

Specifically, Servicewide goals for Vital Signs monitoring (Fancy 2004) are to:

- "Determine status and trends of selected indicators of the condition of park ecosystems to help managers make better-informed decisions and work more effectively with other agencies and individuals for the benefit of park resources.
- Provide early warning of abnormal conditions and impairment of selected resources to promote effective mitigation and reduce management costs.
- Provide data to better understand the dynamic nature and condition of park ecosystems and to provide reference points for comparisons with other altered environments.
- Provide data to meet certain legal and congressional mandates related to natural resource protection and visitor enjoyment.

- Provide a means of measuring progress towards achieving performance goals that are mandated by Government Performance Results Act (GPRA)".

The Great Lakes Network adopts these Servicewide goals and further defines the intentions and limitations of the Network's program with the following provisions:

1. The majority of the Network's funding and efforts will be directed at monitoring trends in resource themes or issues that are common across Network parks and that individual parks would find difficult to accomplish due to high cost, magnitude of scale, or lack of expertise. This commonality across parks and monitoring themes will increase staff efficiency and cost-effectiveness, promote sharing of data, and allow comparison of trends across the Network.
2. In cases where Vital Signs are already being monitored by one or more parks, and the Network assumes the cost of monitoring, the park(s) agree(s) to re-allocate park-based funds and staff to other natural resource efforts in that park. Parks will continue to monitor various resources not monitored by the Network, conduct short-term assessments and field studies, and facilitate research.
3. The Network's monitoring program will be designed with quality of information in mind - not number of issues addressed. The objective is to provide high quality data on a core set of resource indicators. Additional research and park-based monitoring can expand from this core set of indicators.
4. The Network will strive for multiple lines of evidence to document significant changes in resource status. Further, we expect that trends in Vital Signs will provide a basis for developing and testing hypotheses for cause-and-effect research. It is the shared responsibility of the Network, each individual park, the Great Lakes Research and Education Center, and our science partners to uncover important trends in Vital Signs and seek funding to conduct research on the causes and effects of such trends.
5. The Network monitoring program will strive for consistency in long-term data collection yet allow for flexibility to alter or remove indicators that are not meeting objectives.

Monitoring objectives

The Great Lakes Network has refined the Servicewide goals into broad monitoring objectives. These objectives are organized below, in Table 1.2, within six major resource categories as identified by the Servicewide Inventory and Monitoring Program as a framework for tracking and examining Vital Signs across the NPS. These objectives were defined by network staff with park review. They are derived from the Servicewide goals and the Vital Signs selection process (see chapter 3) with due consideration for estimated costs and staff requirements. They provide a broad perspective for the GLKN monitoring program. More specific and measurable monitoring objectives and questions are presented in Chapter 5 and within each protocol.

Table 1.2. Broad monitoring objectives for the Great Lakes Network. Objectives are tied to six resource categories that form a framework for tracking Vital Signs across the National Park Service.

Resource category	GLKN monitoring objectives
Air and Climate	1. Monitor weather patterns and climate, which are major drivers of change and will aid in understanding changes in park ecosystems 2. Assess levels of airborne pollutants, particularly those that are out of compliance with state or federal agencies or that bioaccumulate in park biota
Geology and Soils	3. Monitor geological processes that produce localized, but fundamental, change in important park resources such as sandspits and dunes 4. Periodically assess the properties of soils associated with each park's dominant terrestrial vegetation types
Water	5. Monitor the chemical, biological, and physical components of select inland lakes, rivers, and streams 6. Provide advanced warning of the imminent arrival of targeted aquatic nuisance species in park waters
Biological Integrity	7. Monitor indicators of species diversity, productivity, disease, and succession in dominant terrestrial vegetation types in each park 8. Monitor animal species or communities (e.g., birds, fish, amphibians) whose presence/absence or population status helps evaluate the biotic integrity of the park ecosystems
Human Use	9. Monitor indicators of land use and population growth in areas immediately adjacent to each park to assess the potential relationship between changes observed within and outside of park boundaries 10. Monitor indicators of human use impacts within each park such as water quality
Ecosystem Pattern and Process	11. Monitor changes in land cover and use in and adjacent to each park 12. Monitor ecosystem processes that indicate change or that may aid in understanding changes in other Vital Signs

Performance Management Goals

In accordance with the Government Performance Results Act (GPRA), the NPS must develop 'performance management goals' (GPRA goals) and report on progress towards meeting them. The National Inventory and Monitoring (I&M) Program can help parks attain seven of these goals (Table 1.3). For example, the identification of Vital Signs indicators, goal Ib3, has been accomplished for the nine parks through the efforts of the Network. It may also be appropriate for the Network to monitor certain management actions, such as restoration of disturbed lands, which could help meet other GPRA goals.

Table 1.3. Performance management goals related to inventory and monitoring of parks in the Great Lakes Inventory and Monitoring Network. Class I air quality areas receive the greatest protection, with only small amounts of certain air pollution allowed; 303d-listing designates bodies of water that are out of compliance for particular pollutants; ORW denotes Outstanding Resource Waters.

NPS strategic plan mission goals	Network parks involved
Ia1. Disturbed lands / exotic species – 10.1% of targeted disturbed park lands are restored, and exotic vegetation on 6.3% of targeted acres is contained.	All GLKN parks have invasive exotics and most have disturbed lands, especially INDU, SLBE, and MISS.
Ia2. Threatened and Endangered Species – 14.4% of the 1999 identified park populations of federally listed threatened and endangered species with critical habitat on park lands or requiring NPS recovery actions have improved status, and an additional 20.5% have stable populations.	All nine parks have listed species, but not all have critical habitat and not all species require NPS recovery actions.
Ia3. Air quality – Air quality in 70% of reporting park areas has remained stable or improved.	ISRO and VOYA are Class I air quality areas. ISRO, VOYA, SLBE, and INDU are currently monitoring some aspect of air quality.
Ia4. Water quality – 75% of 288 parks have unimpaired water quality.	303d-listed waters occur in: GRPO, INDU, ISRO, MISS, PIRO, SACN, SLBE. ORW occur in: GRPO, INDU, ISRO, MISS, PIRO, SACN, SLBE, VOYA.
Ib1. National resource inventories – Acquire or develop 87% of the 2,527 outstanding data sets identified in 1999 of basic natural resource inventories for all parks.	All GLKN parks currently benefit from natural resource inventories; all still need additional natural resource inventories.
Ib3. Vital Signs – 80% of 270 parks with significant natural resources have identified their Vital Signs for natural resource monitoring.	All GLKN parks identified their Vital Signs in 2004.
Ib5. Aquatic resources – NPS will complete an assessment of aquatic resource conditions in 265 parks.	Baseline water quality reports are completed for all GLKN parks, but some are ~20 years old.

BACKGROUND

Ecological Overview of the Region

The Great Lakes I&M Network consists of nine national park units in Minnesota, Wisconsin, Michigan, and Indiana (Table 1.4, Figure 1.1). These parks extend from northern Minnesota to southern Lake Michigan, spanning a distance of more than 1,050 km (650 mi). Four parks are located on Lake Superior, two on Lake Michigan, two on major river systems (Mississippi and St. Croix Rivers), and one is associated with a mosaic of large and small inland waters along the border between Canada and the United States. Thus, fresh water is a prominent natural resource shared by these parks. However, terrestrial resources are equally important because of management concerns stemming from a complex of roads, trails, campsites, and land-based facilities across a diversity of habitat types. The following summary provides an overview of the region and puts the parks into ecological context. For a summary of individual parks refer to Appendix A, Supplemental Document 2 or each park's website at www.nature.nps.gov/im/units/glkn/index.htm.

Table 1.4. Great Lakes Inventory and Monitoring Network parks, with park code, area, and primary water association.

Park	Code	Hectares (Acres)	Primary water association
Grand Portage National Monument	GRPO	287 (710)	Lake Superior
Indiana Dunes National Lakeshore	INDU	6,073 (15,000)	Lake Michigan
Mississippi National River and Recreation Area	MISS	21,772 (53,776)	Mississippi River
Apostle Islands National Lakeshore	APIS	28,086 (69,372)	Lake Superior
Sleeping Bear Dunes National Lakeshore	SLBE	28,821 (71,189)	Lake Michigan
Pictured Rocks National Lakeshore	PIRO	28,906 (71,397)	Lake Superior
Saint Croix National Scenic Riverway	SACN	37,544 (92,735)	St. Croix and Namekagon Rivers
Voyageurs National Park	VOYA	88,281 (218,054)	Border lakes and pond complexes
Isle Royale National Park	ISRO	231,494 (571,790)	Lake Superior
Total		471,264 (1,164,023)	

Cultural History

Network parks share a common history. Over the past three centuries, logging, mining, farming, industrial development, the fur trade, and urbanization have dramatically changed the character and ecology of the areas the parks now protect (Wells 1978, Nute 1931). Fur traders began establishing trading posts in the mid-1600s (Ray 1987). Over the next two centuries, Native American and European trappers removed a staggering number of beaver (*Castor canadensis*) and other furbearers from the region (Schorger 1970).

Large-scale logging began in the 1800s. Most of the lands now within the parks were eventually logged to some degree (Wells 1978, Callison 1967). Dams were constructed in the 1800s and early 1900s to aid the transportation of logs and later used for power generation and navigation at MISS, SACN, and VOYA.

Logging began in the mid-1800s in the more southern and eastern areas, and continued northward until the entire region was cleared of trees by the early 1900s. Intense fires often followed logging and destroyed seed sources and organic matter in the soil. Hunting to supply food for logging camps sharply reduced the number of ungulates and led to extirpation of woodland caribou (*Rangifer tarandus*) and eastern elk (*Cervus elaphus*). Logging created habitat more favorable for white-tailed deer (*Odocoileus virginianus*), and the resulting range expansion of deer has significantly altered forest composition in some areas (Rooney et al. 2004, Blouch 1984). Deer also harbor a parasitic brainworm, *Pneumostrongylus tenuis*, which may limit recovery efforts for moose (*Alces alces*) and woodland caribou (Karns 1967). Mining occurred on some lands that are now protected within parks: brownstone at APIS, clay and gravel at SACN, copper at ISRO, gold at VOYA, and sand and gravel at INDU and SLBE.

Current Human Uses

Water levels continue to be controlled by dams within SACN, MISS, SLBE, and VOYA. These dams affect sediment transport, water temperatures and chemistry, and migration and dispersal of aquatic species. Visitors use parks in the region for a variety of recreational activities, including canoeing, motor boating, kayaking, sailing, fishing, hunting, trapping, camping, swimming, hiking, cross-country skiing, snowmobiling, wildlife viewing, and personal solitude.

As some of our nation's most pristine areas, the parks also offer opportunities for scientists and resource managers from state, federal, and tribal agencies to better understand natural processes and to compare protected lands with more disturbed landscapes.

Climate

The region has a primarily mid-continental climate with seasonal temperatures that vary widely between summer highs and winter lows. The large bodies of water associated with these parks moderate temperatures, produce greater precipitation, and induce a slight seasonal shift to later summers on islands and immediate lakeshore areas in the Great Lakes parks (collectively known as 'lake effects'). Mean annual precipitation ranges from 64.5 to 90.7 cm (25.4 to 35.7 in), and temperatures can vary from minus 40 ˚C (-40 ˚F) in winter to over 32 ˚C (90 ˚F) in summer (Table 1.5; Appendix A, Supplemental Document 3). Annual snowfall ranges from 71.1 to 342.6 cm (28 to 135 in). Lake effect snowfall near the Great Lakes causes this wide variation in snowfall within and among parks in the Network. Two entries are included for SACN in Table 1.5 because significant climatic differences exist between the northern (Namekagon River) and southern (Lower St. Croix) reaches of the park due to latitude and topography.

Global climate change could have long-term ecological consequences for the region. Climate models suggest that temperatures around the Great Lakes will warm by 3 to 7 ˚C (5 to 12 ˚F) in winter, and by 3 to 11 ˚C (5 to 20 ˚F) in summer by the end of the 21st century (Kling et al. 2003). Kling et al. (2003) offer evidence that in the Great Lakes region, winters are already becoming shorter, average annual temperatures are getting

Table 1.5. Climate of the Great Lakes Inventory and Monitoring Network parks. Data from the National Climatic Data Center - National Oceanic and Atmospheric Administration (NOAA), Cooperative Summary of the Day (TD3200) data set; Jack Oelfke (NPS NOCA, personal communication) for ISRO. See Appendix A, Supplemental Document 3 for information on how numbers were derived.

Park	Mean annual temperature Average (Range)[1]	Annual precipitation Mean (Range)	Annual snowfall Mean (Range)	Growing season Mean (Range)
	°C (°F)	cm (in)	cm (in)	Number of days
APIS	5.3 (3.4 - 6.9) 41.5 (38.1 - 44.4)	78.5 (47.2 - 116.8) 30.9 (18.6 - 46.0)	234.4 (101.6 - 430.3) 92.3 (40.0 - 169.4)	140 (100 - 180)
GRPO	3.6 (2.7 - 5.7) 38.5 (36.9 - 42.3)	76.7 (55.4 - 99.6) 30.2 (21.8 - 39.2)	165.1 (76.2 - 264.2) 65.0 (30.0 - 104.0)	126 (102 - 146)
INDU	10.1 (8.6 - 11.7) 50.2 (47.5 - 53.1)	90.7 (63.5 - 133.1) 35.7 (25.0 - 52.4)	111.8 (43.2 - 167.6) 44.0 (17.0 - 66.0)	170 (133 - 201)
ISRO[2]	1 (range unavailable) 34 (range unavailable)	66 (range unavailable) 26 (range unavailable)	71 (range unavailable) 28 (range unavailable)	not available
MISS	7.3 (4.8 - 10.5) 45.1 (40.6 - 50.9)	69.9 (29.2 - 102.1) 27.5 (11.5 - 40.2)	134.9 (53.6 - 257.8) 53.1 (21.1 - 101.5)	163 (124 - 207)
PIRO	5.4 (3.0 - 7.1) 41.7 (37.4 - 44.8)	88.1 (65.5 - 121.4) 34.7 (25.8 - 47.8)	342.6 (108.5 - 510.0) 134.9 (42.7 - 201.2)	118 (74 - 176)
SACN - N	5.7 (3.1 - 8.8) 42.3 (37.6 - 47.8)	70.9 (26.7 - 115.1) 27.9 (10.5 - 45.3)	125.2 (45.7 - 247.9) 49.3 (18.0 - 97.6)	119 (72 - 166)
SACN - S	7.8 (5.9 - 10.4) 46.0 (42.6 - 50.7)	77.5 (49.0 - 114.0) 30.5 (19.3 - 44.9)	104.6 (34.5 - 191.5) 41.2 (13.6 - 75.4)	157 (122 - 195)
SLBE	7.6 (6.1 - 9.6) 45.7 (43.0 - 49.3)	87.9 (61.7 - 132.1) 34.6 (24.3 - 52.0)	322.6 (147.3-505.5) 127.0 (58.0-199.0)	148 (93 - 190)
VOYA	6.5 (0.7 - 6.6) 43.7 (33.3 - 43.9)	64.5 (43.4 - 89.4) 25.4 (17.1 - 35.2)	151.1 (63.8 - 330.2) 59.5 (25.1 - 130.0)	122 (59 - 158)

1 =Range, in this case, refers to the range of means in annual temperature.
2 =Data from Isle Royale are estimates; no range available.

warmer, duration of lake ice cover is decreasing, and heavy rain events are becoming more common. If predictions of further changes hold true, groundwater, surface water, wetlands, and other habitats could change dramatically and cause shifts in the distributions of many plants and animals.

Native Vegetation

The Network parks span two ecological provinces described by McNab and Avers (1994) - the Laurentian mixed forest and eastern broadleaf forest. Blouch (1984) also describes the area as a transitional vegetation zone between the boreal forest to the north and broadleaf forests to the south (Figure 1.1).

Quaking and big-tooth aspens (*Populus tremuloides and P. grandidentata*) and paper birch (*Betula papyrifera*) and are often the first tree species to become established following a disturbance. The forest types of less disturbed areas tend to reflect the region's soil and moisture regimes, with gradients existing both north-to-south and east-to-west. Common tree species of northern mesic forests include sugar and red maples (*Acer saccharum, A. rubrum*), red oak (*Quercus rubra*), yellow birch (*Betula alleghaniensis*), white ash (*Fraxinus americana*), basswood (*Tilia americana*), and white pine (*Pinus strobus*). To the east of the Minnesota-Wisconsin border, eastern hemlock (*Tsuga canadensis*) also occurs, and in the Michigan parks, American beech (*Fagus grandifolia*) is a common constituent. Southern mesic forests often contain many of the species found in northern forests with the following additional species: white and bur oaks (*Q. alba and Q. macrocarpa*), hickories (*Carya* spp.), and hackberry (*Celtis occidentalis*). Northern dry forests are typically dominated by jack pine (*Pinus banksiana*), red pine (*Pinus resinosa*), white pine, red oak, aspens, and paper birch. Southern dry forests usually do not contain pines, and instead are dominated by oak species with black cherry (*Prunus serotina*) co-occurring. Black and white spruce (*Picea mariana* and *P. glauca*), tamarack (*Larix laricina*), northern white cedar (*Thuja occidentalis*), black ash (*Fraxinus nigra*), and balsam fir (*Abies balsamea*) prevail in moist, northern forests. Southern wet forests are usually dominated by silver maple (*Acer saccharinum*), boxelder (*Acer negundo*), black willow (*Salix nigra*), green ash (*F. pennsylvanica*), swamp white oak (*Q. bicolor*), American elm (*Ulmus americana*), and cottonwood (*Populus deltoides*).

While forests are the dominant community type throughout the Network, other communities occur in limited areas. Oak savannas, prairies, dunes, and beaches are not widespread, yet constitute important habitats, often with specific park management goals. Wetlands are abundant and include types such as sedge meadow, marsh, swamp, and bog. Several parks contain old fields, some of which are succeeding to forest while others are maintained as part of the cultural history.

Fauna

Although disturbed by past human activities, the Network park ecosystems still contain most species of pre-European settlement wildlife. Extirpation of native fauna and invasion of exotics tend to be greatest at the southern end of the region. The southern areas are highly fragmented, dominated by human development, and include large cities such as Gary, Indiana; Chicago, Illinois; and Minneapolis-St. Paul, Minnesota. The aquatic environment supports a variety of fishes, amphibians, reptiles, semi-aquatic mammals, and waterfowl. White-tailed deer, which have greatly increased in number and range, are the dominant ungulates and have largely displaced moose and woodland caribou. Black bear (*Ursus americanus*), coyote (*Canis latrans*), and red fox (*Vulpes fulva*) are common terrestrial carnivores in the northern parks. Gray wolves (*Canis lupus*), which were extirpated from the contiguous 48 states by the early 1970s except for

ISRO and a small population in northeastern Minnesota, have steadily increased (Mech 2000). In addition to ISRO, wolves now occur regularly in VOYA, GRPO, and SACN and occasionally in APIS and PIRO. Beaver, which were once decimated by the fur trade, are again a major force in shaping the landscape at ISRO, VOYA, and SACN, and to a lesser degree at the remaining parks. Bald eagles (*Haliaeetus leucocephalus*), osprey (*Pandion haliaetus*), and other avian species high on the aquatic food chain are recovering from declines in the middle of the twentieth century caused by DDT and other pollutants (Gerrard and Bortolotti 1988). Migratory songbirds and waterfowl use the Mississippi and St. Croix rivers as major flyways between wintering grounds and summer breeding territories (Bellrose 1980). Similarly, migratory birds use islands at APIS and ISRO as stopovers to rest or stage while journeying across Lake Superior.

Threatened and Endangered Species

Federally endangered species are confirmed present in six of the Great Lakes Network parks (Table 1.6). Indiana Dunes and SACN both harbor three federally endangered species: piping plover (*Charadrius melodus*), Kirtland's warbler (*Dendroica kirtlandii*), and Karner blue butterfly (*Lycaeides melissa samuelis*) at INDU; Kirtland's warbler, Short's rockcress (*Arabis shortii*), and winged mapleleaf mussel (*Quadrula fragosa*) at SACN. The federally threatened bald eagle is present in all nine Network parks while the gray wolf is confirmed present in six. Other federally threatened species in Network parks include Pitcher's thistle (*Cirsium pitcheri*), at INDU, PIRO, and SLBE and Canada lynx (*Lynx canadensis*), at GRPO and VOYA.

Surface Water

Lakes - Six parks border Lake Superior or Lake Michigan (Table 1.4). These Great Lakes exert a dramatic effect on weather, species distributions, and animal migration patterns. Tens of thousands of smaller lakes ranging from < 10 to > 10,000 ha dot the region with density generally increasing from south to north. Voyageurs National Park, for example, has a complex of 30 lakes and hundreds of ponds. Lakes in the region vary greatly in productivity, but are generally ringed with aquatic plants (macrophytes) and provide habitat for fishes, amphibians, reptiles, semi-aquatic mammals, and a variety of waterfowl and other birds (LaBounty 1986).

Rivers - The Upper Mississippi River and its tributaries, including the St. Croix and Namekagon Rivers, span a latitudinal distance of over 1,280 km (800 mi) (Theiling 1996). Numerous smaller rivers and creek systems drain the region's surface waters down the Mississippi River to the Gulf of Mexico (SACN and MISS), northeast through the Great Lakes (GRPO, APIS, ISRO, PIRO, SLBE, and INDU), or north to Hudson Bay (VOYA).

Ponds and other wetlands - Hundreds of thousands of ponds and wetlands are interspersed through the region; like lakes, these become more frequent in the more northerly regions. These ponds and wetlands are sometimes associated with beaver activity, and in such cases, form some of the most productive wildlife habitats in the region (Omart and Anderson 1986, Weller 1986).

Table 1.6. Species with federal status in Great Lakes Inventory and Monitoring Network parks. Colors indicate park status (■ present, ■ probably present, ■ historic). Numbers indicate federal status (1 = endangered, 2 = proposed reclassification from endangered to threatened, 3 = threatened, 4 = proposed delisting, 5 = candidate, 6 = experimental population).

Species	Common name	APIS	GRPO	INDU	ISRO	MISS	PIRO	SACN	SLBE	VOYA
Vascular plants										
Arabis shortii	Short's rockcress					1		1		
Cirsium pitcheri	Pitcher's thistle			3			3		3	
Lespedeza leptostachya	prairie bush-clover					3		3		
Mimulus glabratus var. *michigansis*	Michigan monkeyflower								1	
Platanthera leucophaea	prairie white fringed orchid					3				
Birds										
Charadrius melodus	piping plover	1		1			1		1	
Dendroica kirtlandii	Kirtland's warbler			1				1		
Grus americana	whooping crane			1						
Haliaeetus leucocephalus	bald eagle	3, 4	3, 4	3, 4	3, 4	3, 4	3, 4	3, 4	3, 4	3, 4
Pelecanus occidentalis	brown pelican			1						
Sterna antillarum	least tern			1						
Mammals										
Canis lupus	gray wolf	2	3	2	2	3	2	2	2	3
Lynx canadensis	Canada lynx	3	3		3		3	3		3
Myotis sodalis	Indiana bat			1						
Herpetofauna										
Sistrurus catenatus catenatus	eastern massasauga			5					5	
Invertebrates										
Lampsilis higginsii	Higgins eye					1				
Lycaeides melissa samuelis	Karner blue butterfly			1						
Quadrula fragosa	winged mapleleaf							1,6		

Summary of Past and Ongoing Terrestrial Studies

The majestic nature of many Network parks has long been a draw for researchers of terrestrial ecosystems, with many early studies of terrestrial resources conducted prior to the National Park designations. These early studies (1900 - 1950) tended to focus on the compilation of species lists, especially of a region's flora. For example, plant species lists were compiled for ISRO in 1914 and for SLBE in 1918. More recent terrestrial research has focused on the relationships of species with their larger environment. Common concerns across parks include the effects of deer browse on vegetation, anthropogenic influences on bears, and the role of fire on park ecosystems. Most recently (1990 - present), many studies have addressed habitat issues for taxa of concern. Notable examples include research at INDU on a native lupine (*Lupinus perennis*), the only food source of the federally endangered Karner blue butterfly. Similarly at SLBE, fields that are maintained for cultural reasons were examined for their importance to declining grassland bird communities.

While most terrestrial studies address a single point in time, several have examined longer time frames. Surveys of deer at INDU and MISS, and wolves at ISRO and moose at GRPO, are, or have been, conducted annually. Breeding bird surveys are also conducted annually at most of the Network parks, and a Christmas bird count has been conducted at INDU since 1953. Long-term studies have not been limited to species surveys. In what is considered a hallmark of long-term research, the population dynamics of the wolf-moose predator-prey system at ISRO have been examined since the early 1960s.

A summary of studies of terrestrial resources at the nine parks in GLKN is available in Appendix A, Supplemental Document 4. The authors provide a synopsis of research from each park, with a focus on floral, mammalian, and avian studies.

Summary of Past and Ongoing Aquatic Studies

A variety of aquatic resource investigations have taken place at Network parks since the parks were established (Lafrancois and Glase 2005). At many parks, these studies have been primarily descriptive, providing general characterizations of park waters and assessments of basic physical, chemical, and/or biological conditions. All Network parks have baseline water quality information for at least some of their waters. This information varies in quality, is sometimes dated, and may include early qualitative surveys as well as more recent inventories and quantitative studies. Benthic invertebrate community assessments have been undertaken in several Network parks since the 1980s. Phytoplankton, zooplankton, and aquatic macrophytes are less frequently studied, and functional aspects of aquatic ecosystems (productivity, nutrient cycling, etc.) are not usually considered.

Aquatic wildlife and amphibians have often been the subject of inventory and monitoring efforts, but rarely the topic of specific research programs. Fisheries investigations have varied among parks, but have consisted largely of surveys and assessments. Much of the fisheries information available for parks comes from state investigations. The U.S. Geological Survey (USGS) has streamflow gages in or near all parks except PIRO, which in some cases are used for water quality monitoring or research projects.

Several parks have developed or are developing water resource management plans (SACN, SLBE, VOYA, and ISRO). Water resources scoping projects, assisted by the NPS Water Resources Division, are planned for MISS and PIRO. These documents play a key role in prioritizing research needs and maintaining continuity in park aquatic research activities.

Detailed analyses of trends in water quality using past data are not possible for most GLKN parks because data collection methods were inconsistent, laboratory analysis methods were often undocumented, and other metadata were often lacking. Despite these inconsistencies and the project-specific nature of past water quality sampling, we have been able to determine hints of trends at several parks, as detailed below.

- The draft water resources management plan for ISRO (Crane et al. 2005) summarized trends in water quality as follows. Inland lakes, while sampled incompletely, show no discernable trends from the 1970s to 1990s in chemical and biological parameters, with the exception of a decline in sulfate concentration. Sediment cores from Siskiwit Lake (ISRO) show declines in persistent organic pollutants and poly-aromatic hydrocarbons; lake trout tissue has shown concomitant declines in these and other pollutants.
- Lafrancois et al. (in press) analyzed data from Lake St. Croix (SACN) from 1976 to 2004, and found decreasing trends in total nitrogen, ammonia plus ammonium nitrogen, total phosphorus, ortho-phosphate, total suspended solids, and turbidity; nitrate plus nitrite nitrogen showed an increasing trend; total chlorophyll-*a* and flow showed no significant trends. Similar analyses of data from 1993 to 2003 showed fewer significant trends, however, total chlorophyll-*a* increased, and flow decreased. Triplett et al. (2003) analyzed diatom communities in sediment cores from Lake St. Croix, and concluded that current sedimentation rates are four times that of pre-European settlement times, approximately 170 years ago, and phosphorus loads are approximately three times greater. In response to the increased phosphorus loading, algal abundance and community structure have changed greatly since pre-settlement times.
- Kallemeyn et al. (2003) describe declines in sulfate deposition in the area near VOYA between 1980 and 2000, and show similar declines in the four large lakes. Eleven interior lakes showed an increase in acid neutralizing capacity over the same approximate time period, and a similar, but weak increasing trend in pH.

Axler et al. (2006) conducted exploratory trend analyses of inland lakes at SLBE, PIRO, and INDU, and found dozens of potential trends in several parameters, but predominantly dissolved oxygen, pH, and specific conductance. At SLBE, for example, four lakes showed an increasing trend in dissolved oxygen (linear regression results) in the 1-3 m depth stratum, two lakes showed a similar increase in the 6-7 m stratum, and two lakes showed a decreasing trend in the 1-3 m stratum. At PIRO, two lakes showed decreasing trends in pH - Grand Sable Lake in both the 6-7 m and 13-14 m depth strata, and Legion Lake in both the 1-3 m and 9-10 m strata. Some of these trends may indeed be real, but because Axler et al. (2006) conducted multiple tests without Bonferroni corrections and used a high p-value (10%), their results must be viewed as exploratory. A detailed aquatic synthesis of all nine GLKN parks has been prepared as a technical report (Lafrancois and Glase 2005). For each park, the authors describe the basic aquatic resources; summarize past aquatic-related research, inventory, and monitoring efforts; identify the strengths and gaps in aquatic resource programs; and make recommendations for monitoring and research. This aquatic synthesis also includes information relevant to the Network as a whole, such as a summary of aquatic projects undertaken in parks by aquatic theme (e.g., water quality, contaminants, mussels, fish). The authors point out apparent information needs for inventory, monitoring, and research across the Network, and provide recommendations.

Summary of Water Resource Threats and Legal Status

Water is a major natural resource of the nine GLKN parks, and NPS mandates clearly state the need to protect water resources. The NPS Strategic Plan 2001-2005 provides goals and guidelines for water quality. In the Omnibus Management Act of 1998, Congress required that park managers provide a "*program of inventory and monitoring of the National Park System resources*."

The majority of Network parks have good water quality (Table 1.7). However, the amount of historic water quality data available for each park varies widely, which makes comparisons difficult (see Ledder 2003 for a complete discussion). Atmospheric deposition and surrounding land use practices are two of the most common threats to water quality in the parks. Three parks (INDU, MISS, and SACN) are located in urban settings and have been negatively impacted by residential and industrial activities. Seven parks have one or more waterbodies listed in the corresponding state 303(d) list of impaired waterbodies due to air deposition of toxics and land use practices. Conversely, eight parks contain waterbodies considered to be Outstanding Resource Waters (ORW) by the corresponding state, including seven of the same parks with 303(d)-designated waters (Tables 1.7 and 1.8). Methylation and bioaccumulation of mercury are issues at most, if not all, parks (Crane et al. 2005, Kallemeyn et al. 2003, Ledder 2003).

Regulations for maintaining water quality in Network parks include Water Quality Standards in Minnesota, Wisconsin, Michigan, and Indiana. All but three parks are located in the Great Lakes Basin and fall under the Great Lakes Water Quality Agreement between the United States and Canada.

Summary of Air Quality Information

The NPS Air Resources Division (ARD) conducted a synoptic overview of air quality monitoring considerations for Network parks (Maniero and Pohlman 2003). The following is a summary of conclusions from that report.

Ambient air quality in Network parks appears to be generally well monitored (Figure 1.2). All nine parks have wet deposition (i.e., National Atmospheric Deposition Program/National Trends Network (NADP/NTN)) sites within 56 km (35 mi) of their boundaries. With the exception of VOYA, which has a dry deposition (i.e., Clean Air Status and Trends Network (CASTNet)) site, all other parks are between 72 km (45 mi) and 264 km (165 mi) from the nearest CASTNet site. The distance between parks and CASTNet monitoring is not unusual, given the small number of CASTNet monitoring stations across the country. The relative abundance of wet deposition monitors is probably appropriate because the bulk of the deposition in this area is in the form of wet deposition (Maniero and Pohlman 2003).

Most Network parks have ozone monitors within 40 km (25 mi) of their boundaries. The exception is APIS with the nearest ozone monitor 112 km (70 mi) away.

Table 1.7. Summary of threats to water resources at the nine National Park Service units in the Great Lakes Inventory and Monitoring Network (Ledder 2003). Under legal status, 303(d) = impaired waterbody; and ORW = Outstanding Resource Waters.

Park	State	Data	Current status and threats to water resources	Documented problem parameters*	Waterbody legal status#
Apostle Islands National Lakeshore	WI	1968-1996	Appears to be good quality. Atmospheric deposition and water traffic/recreational use. Highly erodible soils and often severe spring runoff.	None documented	None designated
Grand Portage National Monument	MN	1968-1995	Appears to be good quality. Relatively little water quality data. Atmospheric deposition, light recreational use, and logging in surrounding areas.	Pigeon River outside boundary 303d-listed for mercury	Pigeon River outside boundary is 303(d) listed
Indiana Dunes National Lakeshore	IN	1935-1992	Impacted by industrial/municipal effluents, surface runoff, sulfur and nitrous oxides, altered hydrologic processes, exotic species, and drain and fill of wetlands.	PCBs, PAHs, metals, pesticides, fuels and oils, indicator bacteria, biota	Outstanding Resource Waters (ORW), 303(d) listed waters
Isle Royale National Park	MI	1962-1987	Appears to be very good quality. Atmospheric deposition, visitor activities, and waste.	Mercury, PCBs	303(d) listed waters Whole park ORW
Mississippi National River and Recreation Area	MN	1926-1994	Heavily impacted by industrial/municipal waste water discharges, stormwater runoff, commercial and residential development, contaminated sediments, and erosion.	Dissolved oxygen, metals, indicator bacteria	303(d) listed waters Headwaters ORW
Pictured Rocks National Lakeshore	MI	1968-1984	Appears to be good quality. Atmospheric deposition, surrounding land use practices and development, invasive species, and viewshed impacts.	None documented	303(d) listed lakes Whole park ORW
Saint Croix National Scenic Riverway	WI	1926-1995	Impacted by development, industrial/municipal wastewater discharges, surface runoff, agriculture, cranberry industry, and recreational use.	Dissolved oxygen, metals, indicator bacteria, mercury, and PCBs	ORW rivers 303(d) listed lakes and flowages on the rivers
Sleeping Bear National Lakeshore	MI	1962-1996	Appears to be good quality. Atmospheric deposition, non-native species, septic leakage, wastewater, runoff, and recreational use.	None documented	303(d) listed lakes Whole park ORW
Voyageurs National Park	MN	1967-1991	Appears to be good quality. Atmospheric deposition, human use and adjacent land uses. Naturally occurring low yield aquifers may limit groundwater use.	Mercury, PCBs, fuels, waste water	Whole park ORW

* Denotes historic data gathered in "Baseline Water Quality Inventory and Analysis Reports"
# Denotes Water Quality Standards and state lists.

Table 1.8. Waterbodies with legal designation in the Great Lakes Inventory and Monitoring Network.

Park	Waterbody	Legal status	Reason for 303(d)
APIS	Lake Superior Lake Superior and tributaries for ¼ mile	303(d) 303(d)	FCA for PCBs, Hg, chlordane, dioxin FCA for Hg
GRPO	Pigeon River (outside of park boundaries) Lake Superior	303(d) ORVW	Hg FCA for PCBs, Hg, chlordane, dioxin
INDU	Grand Calumet River Little Calumet River Lake Michigan all waterbodies	303(d) 303(d) OSRW/303(d) OSRW	FCA for PCBs & Hg; CN, oil, pesticides, impaired biota, *E. coli*, Cd, Zn, PAH *E. coli*, CN, pesticides, DO FCA for PCBs, Hg, chlordane, dioxin
ISRO	Siskiwit Lake Lake Superior all waterbodies	303(d) OIRW/303(d) OSRW/303(d)	FCA for PCBs, Hg FCA for PCBs, Hg, chlordane, dioxin FCA-Hg
MISS	Mississippi River Mississippi River (portions)	303(d) ORW	Aquatic life, turbidity, PCB, bacteria
PIRO	Grand Sable Lake Lake Superior all waterbodies	303(d) OIRW/303(d) OSRW/303(d)	Hg FCA for PCBs, Hg, chlordane, dioxin FCA for Hg
SACN	St. Croix Flowage Minong Flowage Yellow Lake Mud Hen Lake Sunrise River Goose Creek St. Croix River Namekagon River Kettle River	303(d) 303(d) 303(d) 303(d) 303(d) 303(d) ORW/303(d) ORW ORW	Hg Hg Hg Hg Aquatic life, impaired biota, indicator bacteria Excessive nutrients Bioaccumulative toxins
SLBE	Lake Michigan Big Glen Lake Little Glen Lake all waterbodies	303(d) 303(d) 303(d) OSRW/303(d)	FCA for PCBs, Hg, chlordane, dioxin FCA-PCB, chlordane, Hg FCA-PCB, chlordane, Hg FCA for Hg
VOYA	all waterbodies	ORVW/303(d)	FCA for Hg

303(d) = impaired waterbody
PAH = polycyclic aromatic hydrocarbon
PCB = polychlorinated biphenyl
OIRW - outstanding international resource water
ORVW = outstanding resource value waters (MN designation)
ORW = outstanding resource waters (WI Designation)
OSRW = outstanding state resource waters (IN & MI designations)
FCA= fish consumption advisory for atmospheric deposition
Hg = mercury

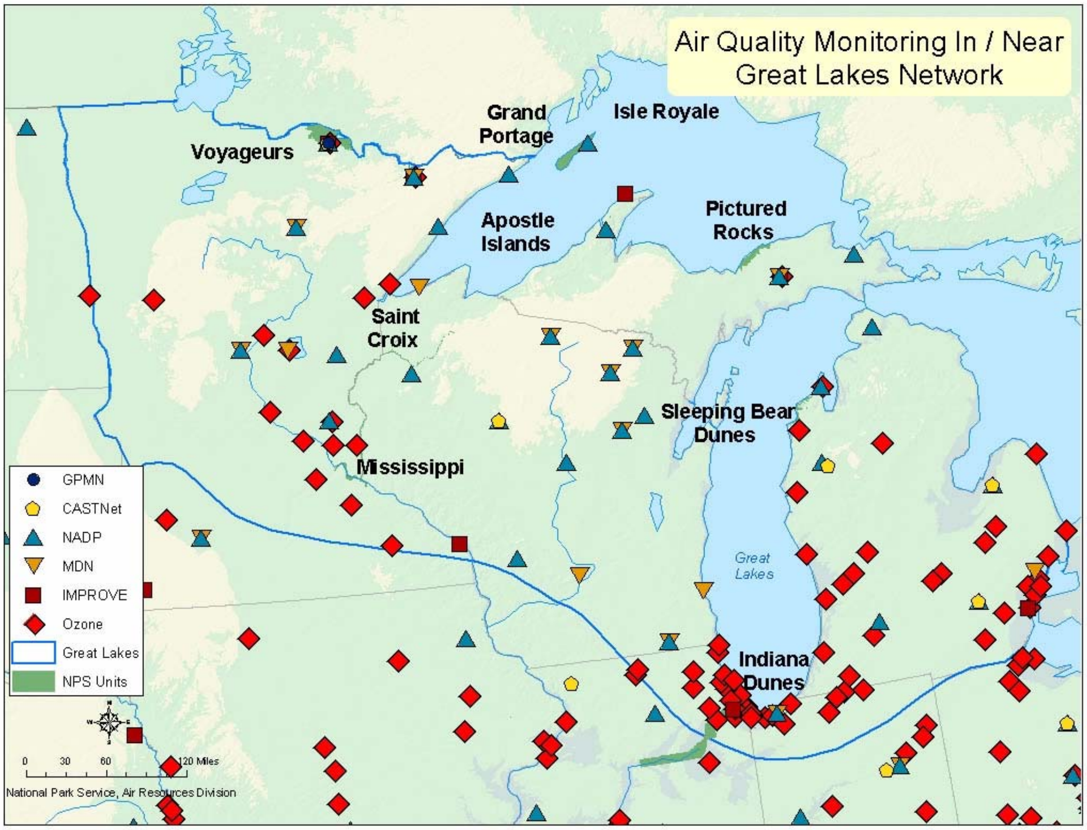

Figure 1.2. Location of air quality monitoring stations in the area surrounding the Great Lakes Inventory and Monitoring Network. GPMN = Gaseous Pollutant Monitoring Network, CASTNet = Clean Air Status and Trends Network, NADP = National Atmospheric Deposition Program, MON = Miscellaneous Organic National Emission Standards for Hazardous Air Pollutants, IMPROVE = Interagency Monitoring of Protected Visual Environments.

Parks with Class I airsheds have either on-site (VOYA) or nearby (ISRO) Interagency Monitoring of Protected Visual Environments (IMPROVE) monitors. (Class I, II, and III areas are Congressional classifications designed to prevent deterioration of air quality. Class I airsheds receive the greatest protection and Class III the least.) For other parks, proximity to an IMPROVE monitor largely depends on how close the park is to a Class I park or another Class I area (such as the Boundary Waters Canoe Area Wilderness or the Seney National Wildlife Refuge (NWR)). The distance of parks with Class II airsheds from IMPROVE monitors range from 40 to 224 km (25 to140 mi). Monitoring visibility at scenic vistas with digital cameras is possible; while not adequate for regulatory purposes, it is useful for documenting visibility conditions and trends and providing a means of sharing that information with the public. Cameras are currently located at Seney NWR, Michigan, approximately 50 km (31 mi) from PIRO, and Grand Portage Indian Reservation, Minnesota, adjacent to GRPO (www.mwhazecam.net/).

A fair amount of ambient air toxics monitoring has been and is being conducted in the Great Lakes area. These efforts do not seem to be well coordinated on a regional basis, and the data from the various monitoring programs are not readily available. Air toxics may be an issue for many Network parks. A great deal of monitoring and research on these toxic effects has been conducted at INDU, ISRO, MISS, SACN, and VOYA. For good reason, monitoring at ISRO and VOYA has focused on mercury and its effects. Additional previous work at ISRO focused on atrazine and PCBs. Very little, or no, monitoring on the effects of air toxics has been conducted at APIS, GRPO, PIRO, or SLBE. The ARD also looked at park water quality data relative to atmospheric deposition for all nine Network parks. The data indicated that surface waters at APIS (i.e., island lagoons) are sensitive to acidification from atmospheric deposition. Nitrogen deposition associated eutrophication may be a concern for INDU and MISS.

Ozone sensitive vascular plant species have been identified for all of the parks in the Network. Ozone concentrations may be high enough in INDU, PIRO, and SLBE that foliar injury surveys are warranted. An ARD-funded risk assessment completed for Network parks in June 2003 provided further guidance on the likelihood of ozone-induced vegetation damage.

Summary of Current Monitoring in Parks

Network staff are cataloging and evaluating monitoring projects that are ongoing in the nine parks. This work is a component of the overall data mining effort being conducted by the Network's data specialists. The extent of monitoring efforts varies among parks, and is a consequence of park size, longevity, and natural resource program funding.

Network-wide, at least 217 projects with over 1,300 cumulative years of data collected have been conducted by NPS staff, other agencies, and academic partners (Table 1.9). The number of projects is subjective, however, because each park counts them differently. For example, one park may count five field sessions to monitor five species of invasive plants as five projects, while another park may count the entire effort as one monitoring project for invasive plants. Regardless, Figure 1.3 and Table 1.9 illustrate the relative effort among natural resource subjects. The greatest monitoring efforts in parks have been on birds, plants, and water quality, in that order. Much of the bird monitoring follows standardized protocols such as those of the breeding bird survey (BBS), or those recommended by Howe et al. (1997), but significant efforts are directed at specific species or assemblages such as the bald eagle, piping plover, and colonial water birds. Most plant monitoring revolves around non-native, sensitive, and rare species. Some selected plant communities (e.g., sand dune communities) or species (e.g., Canada yew (*Taxus canadensis*) are also being monitored and several parks are cooperating with the U.S. Forest Service to gather Forest Health Monitoring (FHM) plot data. Most Network parks or their partners are monitoring basic water chemistry and some indication of flow or lake level. Other significant efforts include air quality, fire effects (fuels and vegetation changes), fish communities, amphibian call surveys, white-tailed deer, and human impacts. The most notable long-term study is the wolf/moose predator prey study on Isle Royale. This study is currently conducted by Rolf Peterson from Michigan Technological University with support from the NPS. The study has been conducted, without interruption, for over 40 years, and has resulted in numerous scientific and public interest publications. Refer to Appendix A, Supplemental Document 5 for a complete listing and abstracts of unpublished reports on ecological monitoring in

Network parks, and Supplemental Document 6 for important published literature on ecological monitoring.

Current monitoring projects within the Network parks provide a good basis for a more focused monitoring program. Considerable information can be gleaned from these projects. For example, data variability, logistical constraints, and relative estimates of cost will all be essential for the future development of the Network program. Unfortunately, few of these efforts are well analyzed and reported. In 2003, the Network contracted with the University of Minnesota, Natural Resources Research Institute (NRRI) to analyze and summarize water quality monitoring data collected in the nine parks. In their draft report, they made recommendations for improvement in monitoring methods at several Network parks. The Network also hired a private contractor in 2003 to critique the parks' monitoring of herpetofauna (Casper 2004). The contractor's final report included recommendations for consistency across the parks as well as for methods specific to individual parks. In FY04, the Network selected contractors to assess park data for the additional monitoring themes of bioaccumulation of toxins, terrestrial vegetation, breeding landbirds, and deer browse.

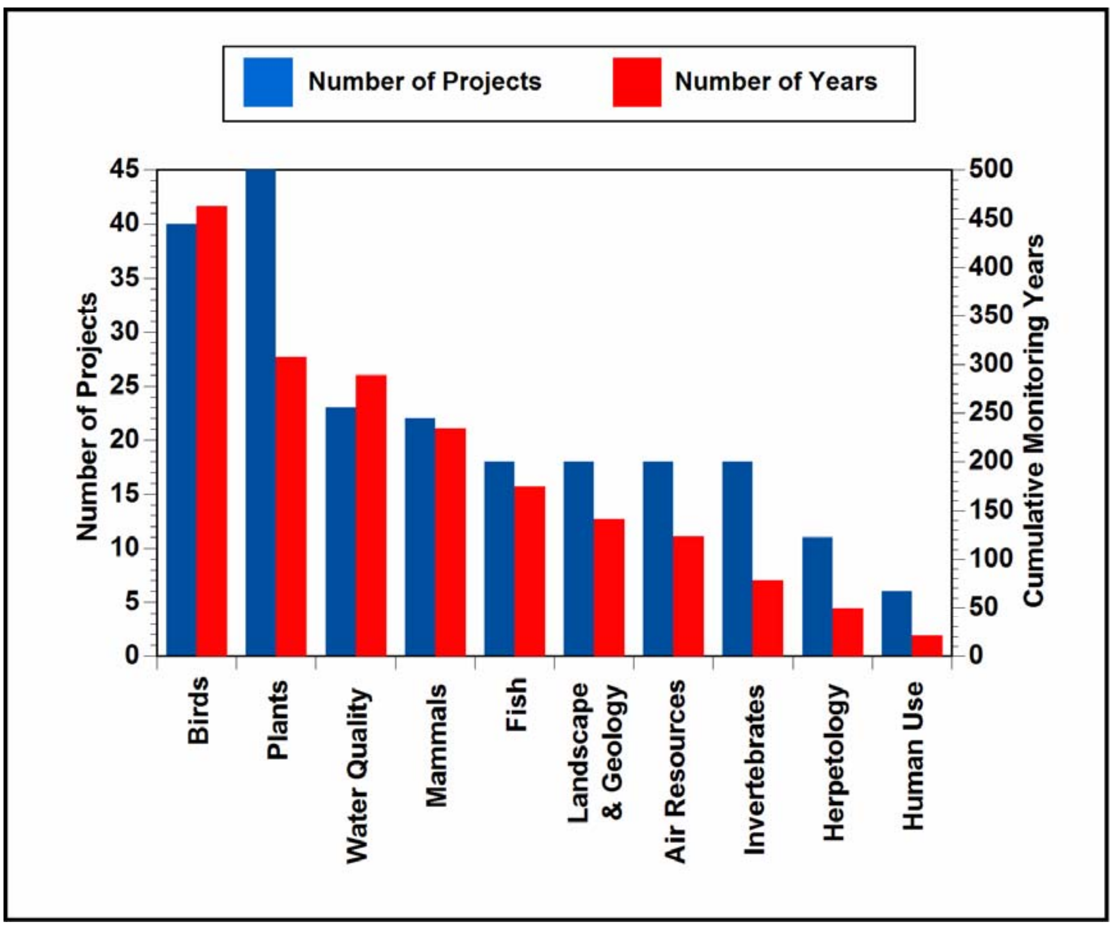

Figure 1.3. Summary of the number of projects and cumulative years of data collected for all known monitoring activities in National Park Service units of the Great Lakes Inventory and Monitoring Network. This summary includes efforts by NPS staff and numerous other agency and university partners.

Table 1.9. Past and current monitoring efforts by the National Park Service and its partners in the Great Lakes Inventory and Monitoring Network. Numbers reflect total known projects in each category as of December 2004.

Ecosystem component	Great Lakes Network Parks									
	APIS	GRPO	INDU	ISRO	MISS	PIRO	SACN	SLBE	VOYA	Total
Air resources										
Meteorology			1	1				1	1	3
Air quality	1		1	1				1	1	5
Ozone			1	1					1	3
Mercury and other pollutants			1					1		2
Wet deposition			1	1					1	2
Fire weather			1					1		2
Water quality										
Physical: temp., cond., pH, clarity	1	1	1		3	1	1	1	2	11
Nearshore bacteriology			1					1		2
Riparian – Riverwatch			1		1					2
River flow/river flow/lake levels					2		2	1	1	6
Sedimentation					1			1		2
Geology and landscape processes										
Bluff erosion	1							1		2
Sandscape/beach erosion	1		1			1	1			4
Fire/habitat processes			3	2					1	6
Hydrology								2		2
Land use monitoring					3			1		4
Plants										
Selected plant communities	2	1	2		1	1		1	1	9
Exotic plants	2		2	1	1	2	2	4	1	15
Sensitive, rare and threatened plants	2		3	1		1	1	3		11
Plant health and disease			1	1		2			2	6
Invertebrates										
Aquatic invertebrate communities					2				1	3
Sensitive, rare and threatened species			1				1	1		3
Gypsy moth	1		1	1		1		1	1	6
Zebra mussel						1	1	1	1	4
Other exotic invertebrates				1					1	2
Fisheries										
Salmonids – coaster brook trout, etc.		1		1		1				3
Nearshore fisheries		1	1						1	3
Sportfish harvest									4	4
Fish ecosystem					3		1		3	7
Exotic fish						1				1
Reptiles and amphibians										
Anuran call survey	1		1	1	1	1	1	1		7
Other herp community				1			2			3
Amphibian deformity				1						1
Birds										
Breeding bird survey	1	1	1	1	1	1	1		1	8
Migratory bird survey	1									1
Winter bird survey							1			1
Colonial waterbirds	1		1	1			1	1	2	7
Game birds	2	1								3
Bald eagle	1			1		1	1	1	2	7
Piping plover	1		1			1		1		4
Other avian T&E species							1	1		2
Special concern avian species			5	1				2	2	10
Mammals										
Ungulates	1	1	2		1			1	2	8
Beaver	1			1			1		2	5
Black bear	1					3			1	5
Timber wolf				1						1
Other mammal							2		1	3
Human uses										
Human impacts				1			3	1	1	6
Total	22	7	35	22	20	19	24	32	33	217

Significant Monitoring Programs in the Great Lakes Region

Several important monitoring efforts are being conducted by partners around the region. Most of these are captured in the 'current monitoring' discussion above. Three additional programs that are significant to the Network's goals are summarized below.

State of the Lakes Ecosystem Conference (SOLEC): http://www.epa.gov/glnpo/solec/

Canada and the United States are parties to the Great Lakes Water Quality Agreement (GLWQA). In 1994, the U.S. Environmental Protection Agency (EPA) and Environment Canada began hosting the biennial State of the Lakes Ecosystem Conferences (SOLEC) to report on the condition of the Great Lakes ecosystem and the major factors impacting it. After each conference, the EPA and Environment Canada prepare a report on progress towards achieving the purpose of the GLWQA: *to restore and maintain the chemical, physical, and biological integrity of the waters of the Great Lakes Ecosystem*. The SOLEC partners include all major federal, state, and provincial agencies, and NGOs in both countries. The partners have selected 80 indicators that reflect conditions of the Great Lakes basin and its major components. Currently 33 indicators are being reported on, but more indicators are incorporated at each conference.

The Network considered the 80 SOLEC indicators during focus meetings for the selection of Vital Signs. Many of the SOLEC indicators are not appropriate to the GLKN because of scale and different goals; however, some were included on GLKN's list. The Network's coordinator serves on the SOLEC Steering Committee.

Great Lakes Ecological Indicators (GLEI) program: http://glei.nrri.umn.edu/default/

The EPA funded the University of Minnesota's Natural Resources Research Institute to conduct a four-year evaluation of ecological indicators for the Great Lakes Basin. The study involves a rigorous research design to test field methods, statistical models, measurability, and overall relevance of a suite of indicators for nearshore and terrestrial components of the Great Lakes Basin. The field portion of the study concluded in 2005 and data analyses will continue for one to several years. The principal investigator for the GLEI program serves on GLKN's Science Advisory Group (SAG) and other NRRI employees are involved in analysis of past data and in helping develop protocols for the Network.

Amphibian Research and Monitoring Initiative (ARMI): www.armi.usgs.gov

The USGS Amphibian Research and Monitoring Initiative (ARMI) formed in 2000 over concern for worldwide population declines and physical deformities in amphibians. Because of their close association with aquatic habitats and sensitivity to environmental stresses, amphibians are good indicators of ecosystem health. The purpose of ARMI is to measure, understand, and respond to the effects of environmental change on the nation's amphibians. The ARMI coordinator for the North Central region, who serves on GLKN's Science Advisory Group, is stationed at the Upper Midwest Environmental Science Center in La Crosse, Wisconsin. The Network and ARMI have a joint project to inventory amphibians and reptiles at SACN, MISS, and VOYA.

Forest Inventory and Analysis (FIA)t: www.fia.fs.fed.us

The forest inventory and analysis program (FIA) is managed by the USDA Forest Service in cooperation with state forestry programs and private industry. FIA has been in operation under various names (e.g. Forest Survey) for over 70 years. The program reports on status and trends in forest area; composition, size, and health of trees; in total tree growth, mortality, and harvest; in wood production and utilization rates; and in forest land ownership. The Forest Service has recently enhanced the FIA program by changing from a periodic survey to an annual survey (i.e. monitoring) and by expanding the scope of data collection to include soil, under story vegetation, tree crown conditions, coarse woody debris, and lichen community composition. The Great Lakes Network is currently intending to monitor terrestrial vegetation using methods that conform to FIA so that network data can be put in to regional context with this extensive dataset.

USGS Long Term Resource Monitoring Program: http://www.umesc.usgs.gov/ltrmp.html

The Long Term Resource Monitoring Program is being implemented by the U.S. Geological Survey (USGS) in cooperation with the five Upper Mississippi River System states (Illinois, Iowa, Minnesota, Missouri, and Wisconsin), with guidance and overall responsibility provided by the U.S. Army Corps of Engineers. Congress has recognized the Upper Mississippi River System as both a nationally significant ecosystem and a nationally significant commercial navigation system. The long-term goals of the Program are to understand the system, determine resource trends and impacts, develop management alternatives, manage information, and develop useful products. The Great Lakes Network has engaged USGS scientists involved with this program to help develop ecosystem models and we have learned from many of their past efforts.

USGS - Water Resources Discipline: www.*water.usgs.gov/programs*

There are several USGS WRD programs active in the Great Lakes region and the upper Mississippi River Basin. These include: the Cooperative Water Program, a partnership between the USGS and state and local agencies; the National Streamflow Information Program (NSIP) for the delivery of streamflow information; the National Water Quality Assessment Program (NAWQA), which since 1991, has helped develop long-term data on streams, ground water, and aquatic ecosystems, and the Biomonitoring of Environmental Status and Trends (BEST) Program, which has conducted long-term research and assessments of the effects of contaminants on the upper Mississippi River.

Other programs:

In addition to the above large-scale monitoring programs, each of the four states and some local jurisdictions (e.g. Minneapolis-St. Paul Metropolitan Council) that surround the network parks monitor a variety of natural resources. States routinely monitor water quality, fish and wildlife populations and harvest levels, amphibians, the release and accumulation of toxic chemicals, forest resources, and a variety of rare and exotic species. It is beyond the scope of this document to summarize this extensive work; each protocol will delve in more detail in to relevant state monitoring efforts. The Great Lakes Network is making every attempt to be consistent with other state and federal programs if it meets our objectives and is scientifically defensible.